Visual Analysis of Engineers' Biographies and Engineering Branches

Christofer Meinecke* and Stefan Jänicke*

*Image and Signal Processing Group, Institute for Computer Science, Leipzig University, Leipzig, Germany
E-mail: Christofer.M@gmx.de, stjaenicke@vizcovery.de

***Abstract*—The Prosopographic Database of German Engineers 1825–1970 contains a multitude of biographical information. Given a set of research interests by collaborating historians, this paper discusses the steps undertaken (1) to extract engineering subjects from unstructured text entries in the database accompanied with geospatial and temporal information, (2) to adapt existing visual representations to facilitate exploratory analyses, and (3) to design a visual interface to support the interactive composition of engineering branches from engineering subjects to enable the comparative analysis of geospatial-temporal developments in engineering. Usage scenarios outline the benefit of the proposed visualizations for modern prosopography research.**

***Index Terms*—visual exploration, prosopographic visualization, digital humanities**

I. Introduction

In recent years, many modern prosopography projects have begun collecting and storing biographical information on various groups of people. For example, the "Deutsche Biografie" [2] is a comprehensive database that contains information about around 730,000 German personalities. A full-text search and a typical faceted search interface that operates on the basis of controlled vocabulary support filtering the data. However, visual means that become more and more important for digital humanities research [17] are not provided to explore the database (only a map to filter by location). Other prosopographical databases focus on a narrowly-defined person group. For example the Bavarian Musicians Encyclopedia Online (German: "Bayerisches Musiker-Lexikon Online (BMLO)") [1] that contains biographical information about around 30,000 musicians related to Bavaria. A variety of visualization tools have been developed to support investigating different digital musicology research questions. While Khulusi et al. [19] proposed a visual exploration system to analyze collective biographical information about the musicians, the tool MusikerProfiling [16] serves to discover musicians with similar careers. Both works outline the usefulness of interactive visualizations for the modern prosopography.

Like the latter two examples, this paper focuses on a limited set of persons; German engineers from 1825 to 1970 listed within the Prosopographic Database of Engineers (German: "Prosopographische Datenbank von Maschinenbauern (PDM)") [4]. In addition to the goal of being able to visually explore the different biographical characteristics of engineers and to implement a profiling functionality (cf. [16]), the collaborating historians aimed at investigating research questions on the geospatial-temporal development of engineering sciences in general, and the three branches materials, manufacturing and construction in particular:

- What are the differences between these three branches?
- Which branch had the largest geographical movements?
- When did a branch change its technical terms?

Each of the above mentioned branches can be seen as a composition of engineering subjects. Unfortunately, the given database neither contains structured information about subjects an individual engineer practiced or taught, nor an assignment of engineering branches to engineers. Therefore, the above listed questions could not be answered straightforwardly. Fortunately, the subjects appear in various biographical entries, so that we could annotate each engineer with a list of subjects after a rule-based named entity recognition in a first step, and, in a second step we designed a tool that supports interactive engineering branch construction on the basis of engineering subjects. Figure 1 shows another issue of the database; numerous biographical details of many engineers are missing. Personal information like name and title are almost complete, but not worth to be used for exploratory purposes. Thus, the main focus of this work was on lectureships and assistances as those entries contained topical (subjects), geospatial (institution) as well as temporal (tenure) information. The remaining details are shown when inspecting individual biographies.

II. Related Work

Our work focuses on the development of visual interfaces to support digital humanities research. As visualization became a valuable instrument to discuss and argue inquiries in the

Data fields	%	Data fields	%
Academic title	99.3	Field of study	13.6
Last name	100	university	13.8
First name	97.2	lectureships	36.3
Date of birth	19.7	assistance	79.2
Place of birth	18.7	Other workplaces	8.9
Date of death	13.5	memberships	6.2
Place of death	11.7	relationships	4

Fig. 1: Available entries by engineer attribute

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humanities, many existing techniques have been adapted or developed to support digital humanities research. A comprehensive overview of close and distant reading techniques for the visual analysis of text is given by Jänicke et al. [17]. Windhager et al. [32] surveyed visual exploration systems for cultural heritage collections, but they explicitly excluded visualizations for prosopographical databases. Below, we give an overview of visualizations designed to communicate biographical databases and personal relationships.

Many works in the digital humanities and, in particular, prosopography research focus on visualizing social networks. Weaver embeds an attribute relationship graph in his visual analytics environment to visualize the relationships between movie actors [30]. Visualizations also attend to the matter of visualizing large social networks and their navigation by various interaction means [25]. The design of such visualizations is especially important for the exploration of online social networks [11], [12]. A very common task in digital humanities research is extracting characters from literary works and visualizing the relationships among them. For example, Klein illustrates Thomas Jefferson's social relationships in the form of an arc diagram [20]. Chen et al. [7] introduced tapestries as visual means to explore emotions and the roles of characters in slave narratives. Euler diagrams can be used to visualize clusters in social networks while also showing relations among clusters [26]. Another form of social networks are genealogies expressing familial relations [6]. HistoGraph [23] focuses on historical social multimedia collections and serves, among others, for visualizing the social networks of politicians. For visualizing the time-dependent social network of teachers in musicology [15], nodes representing musicians are fixed on the time axis, and the force-directed layout approach only effects vertical movements. TimeSlice [33] is a traditional timeline visualization for exploring engineers, scientists, philosophers and politicians that can be arranged in different groups to support comparative analyses. Windhager discusses the value of space-time cube visualizations for prosopographical databases [31] as biographical information often relate to space and time as in the work by Schich et al. [27] who explore geospatial-temporal developments by analyzing birth and death locations of around 150,000 notable individuals.

As stated in the introduction, other projects also focus on narrowly-defined person groups. An example is the Linked Jazz project [3] that provides various visual representations (e.g., barycenter drawing, visualization of cliques) to explore relations between around 2,000 Jazz musicians, and the resulting social network comprising around 19,000 relationships can be interactively analyzed [24]. Another example is MusikerProfiling [16] from which we adapted the profiling system. It provides stream graphs, maps and a social network view to discover musicians with similar careers.

Many works applied preprocessing procedures similar to our approach. NEREx [9] is a framework for interactive visual analysis of multi-party conversations, and it offers multiple views to support exploring relationships between named entities, which were extracted with a rule-based named entity recognition in a preprocessing step. Other examples are TimeLineCurator [10], a tool that uses entity extraction to create timelines out of unstructured text and VAiRoma [8] that uses named entity recognition to extract locations and dates out of Wikipedia articles to illustrate the history of Rome.

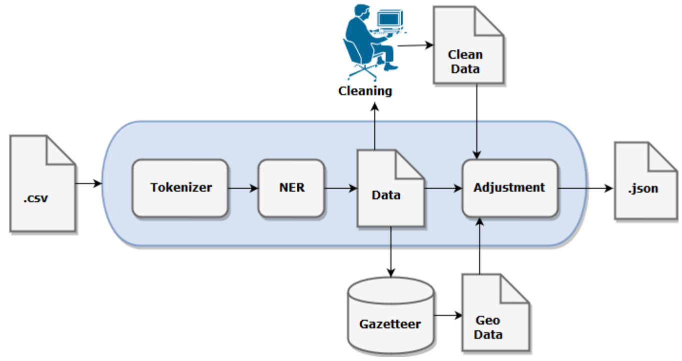

Fig. 2: Information extraction process

III. Database

The Prosopographic Database of Engineers contains biographical information, e.g., subjects, lectureships, assistance, workplaces and memberships, about more than 4,000 German engineers who lived between 1800 and 1970 and worked at universities or other research institutes. The information extraction process is illustrated in Figure 2. The database was given in CSV format. Most colums only contained personal information to be shown for individual engineers, and could not be used for exploratory purposes related to space, time and topics (see Figure 1). But the entries on lectureships and assistances of the observed engineer comprised this information. In order to extract the information about the subjects, datings, locations and institutions, a rule-based named entity recognition approach [22] was crafted as the historian used a recurring pattern when writing down information on employments.

In most cases, the pattern began with the date followed by the academic position of the engineer. Then, usually the signal word *für* (for) and *an der* (at the) [followed by a location or institution] wrapped potential subjects. An example of a lectureship is *1966 Dozent für Machinenbau an der TH Aachen, 1967 Dozent für Mechanik ebd., 1970 Professor für Machinenbau an der TU Berlin*, and the rule applied here is:

```
DATE_POSITION_fuer_SUBJECT_an der_UTYPE_UCITY
if "ebd." take UTYPE and UCITY from previous tenure
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The result is:

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DATE | POSITION  | SUBJECT     | UTYPE | UCITY
1966 | Dozent    | Machinenbau | TH    | Aachen
1967 | Dozent    | Mechanik    | TH    | Aachen
1970 | Professor | Machinenbau | TU    | Berlin
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As several exceptions occurred when applying the proposed named entity recognition rules, we used a list-based approach with controlled vocabulary about subjects complementary to the rule-based approach to minimize the error. Another benefit of the list-based approach was that a full list of all subjects of

507x Maschinenbau	99x Maschinenkunde
250x Mechanik	93x Fördertechnik
239x Maschinenelemente	93x Wärmetechnik
186x Fertigung	80x Getriebe
184x Werkstoffkunde	70x Strömungslehre
168x Verfahrenstechnik	64x Festigkeit
157x Werkzeugmaschinen	60x Kolbenmaschinen
131x Thermodynamik	58x Metallkunde
129x Fertigungstechnik	57x Werkstofftechnik
109x Technische Mechanik	57x Schweißtechnik

Fig. 3: 20 most frequent subjets

the dataset could be generated. This list was used to tag each engineer with related subjects. For example, an engineer with the subject *industrielle Fertigung* (industrial manufacturing) received the subject tag *Fertigung* (manufacturing). After finishing this step we received a list of subject tags, the 20 most frequent tags are listed in Figure 3.

We used GeoNames[1] as gazetteer to enrich the data with georeferences for the extracted location names to be used for geospatial mapping. After dataset curation and enrichment, we processed a JSON file containing all information of the Prosopographic Database of Engineers in a structured, easily processible format.

IV. Visual Interfaces

In order to support a multifaceted analysis of the engineers' biographies, we designed various visualizations, each one serving a different purpose. In addition to discussing design considerations, we provide usage scenarios for all visual interfaces.

A. Multiple Views for Exploratory Analyses

A series of multiple linked views gives a first impression on the contents of the database (see Figure 4). For the user task to *explore* the database, tag clouds were used to giving an appropriate overview. Tag clouds were chosen as they do not need a lot of cognitive effort, and their usefulness for browsing purposes is well-known [29]. The membership tag cloud (Fig. 4a) displays the memberships of engineers listed in the dataset. Although such information is given only for a few engineers (approx. 250), it turned out to be a valuable starting point for exploratory analyses. The most important visualization is the subject tag cloud (Fig. 4b) listing all subjects extracted from assistances and lectureships of all engineers. The frequency of a subject (i.e. how often it was taught) is encoded by font size. Figure 4c gives an overview of the institutions where engineers taught using a TagPie [14], which separates different university types, e.g., Universität (university), TU (technical university) or Bergakademie (mining academy). Mandatory for geospatial-temporal analyses, tenure locations are aggregated on the map (see Fig. 4d) and the years of tenures are shown on a timeline; for both views we adapted the tool GeoTemCo [18]. The advantage of using GeoTemCo is the simultaneous presentation of time and locations, to support analyzing the geographical movement and the change in technical terms. In order to allow a multifaceted analysis of the database, various filters can be defined, e.g., selecting a subject in the subject tag cloud removes all information about engineers not associated with that subject from the visualization. Also, geospatial (selecting a certain university or region) or temporal filters (selecting a period of time) can be set. The design of our system follows Shneiderman's Information Seeking Mantra [28] "Overview first, zoom and filter, then details-on-demand." We first provide an overview of various biographical features, so that patterns get discernable. For exploration purposes, we provide means to zoom to these patterns and to filter out engineers insignificant for the current research inquiry. Details-on-demand are served when the user selects a specific engineer. Then, a close reading view pops up listing all biographical information, e.g., a timeline arranging all assistances, lectureships and memberships of the selected engineer in temporal order as shown in Figure 4e.

NSDAP-memberships: Exploring the database, most memberships (but only 87) are recorded for the NSDAP, the German Nazi Party that existed between 1920 and 1945. Applying the corresponding filter reveals that most of 87 engineers worked at technical universities in Dresden, Braunschweig and Berlin. Selecting TH Braunschweig returns 19 engineers, one of whom is Adolf Busemann. His timeline (see Fig. 4e) illustrates that he emigrated to the United States after World War II, as he became NASA scientist in 1946. Later, he held a professorship in Boulder, Colorado.

B. Profiling Engineers

In order to support discovering engineers with similar biographies, we adapted the MusikerProfiling system [16] to the prosopographical engineers database E. Focusing on one certain engineer $e_i \in E$, the profiling system compares different biographical characteristics with all other engineers $e_j \in E$ and delivers those with the most similar careers. Therefore, we define a similarity function composed of seven similarity measures focusing on subjects, assistances, lectureships, positions, memberships as well as locations and dates of tenures. Each similarity measure S_k $(1 \leq k \leq 7)$ is defined by the Jaccard index like

$$S_k(e_i, e_j) = J\Big(f(e_i), f(e_j)\Big) = \frac{|f(e_i) \cap f(e_j)|}{|f(e_i) \cup f(e_j)|}$$

with $f(e_i)$ and $f(e_j)$ being the two sets of values for the observed biographical dimension, and the similarity between two engineers e_i and e_j is

$$S(e_i, e_j) = \sum_{k=1}^{7} w_k \cdot S_k(e_i, e_j).$$

Depending on the research question at hand, the individual similarities can be weighted differently, thus, the parameter w_k supports iterative adjustment. Also, mandatory attributes can be defined for a profiling step, for example, to require that

[1]http://www.geonames.org/

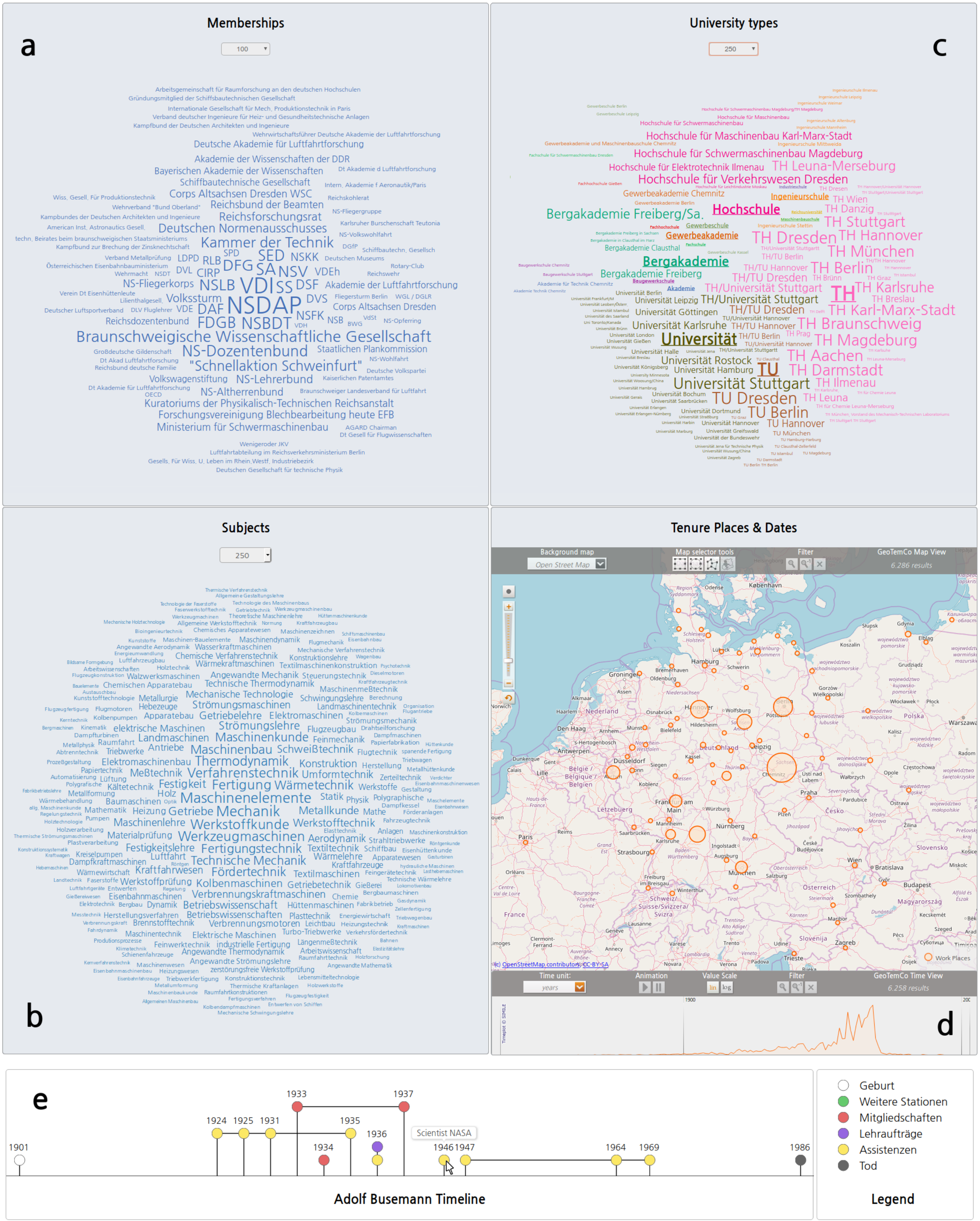


Fig. 4: Linked views: a tag cloud for memberships (a) and subjects (b), a TagPie for university types (c), map and timeline for tenure locations and dates (d), and the timeline of Adolf Busemann (e).

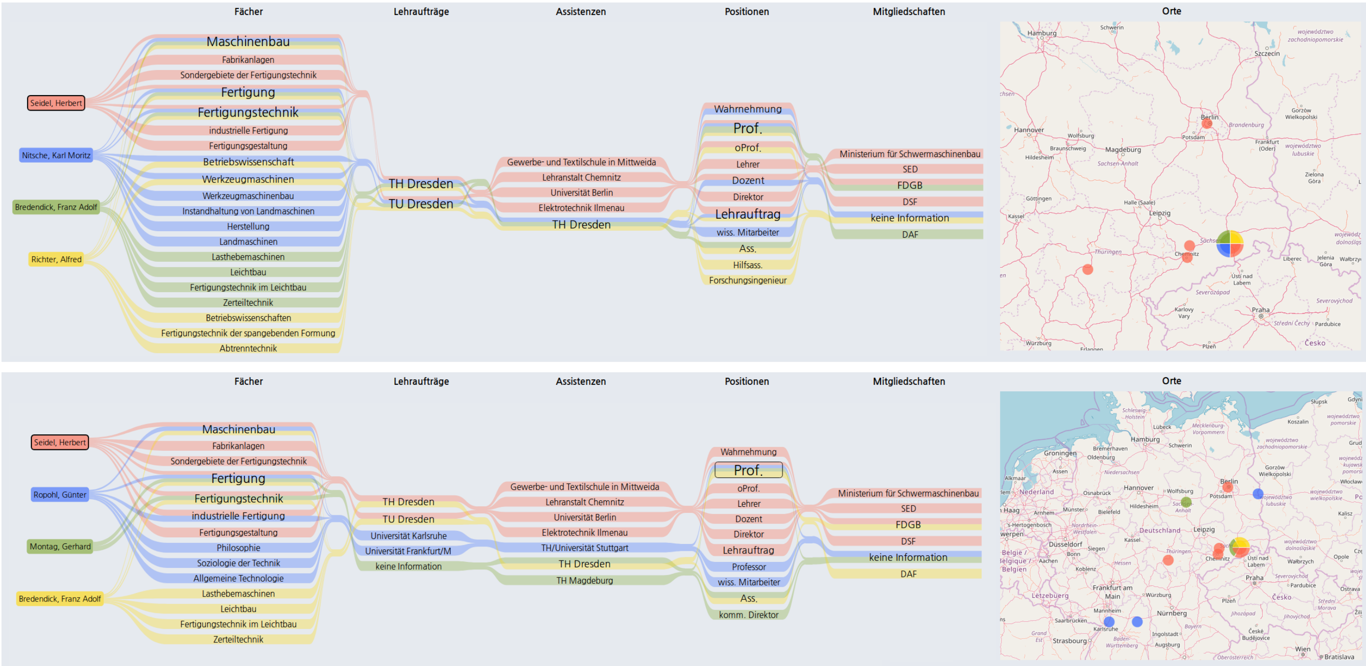


Fig. 5: Profiling Herbert Seidel

Mechanik (mechanics) needs to be a subject of an engineer, or that the engineer needs to have had a position in *Dresden*. As in MusikerProfiling, a stream graph connects biographical information, and a map displays the tenure locations of an engineer. A relationship graph is not provided due to the missing information in the engineers database.

Profiling Herbert Seidel: Figure 5 illustrates a profiling scenario for Herbert Seidel, an engineer who taught many manufacturing subjects (e.g., Fertigung, Fertigungstechnik, Fertigungsgestaltung). With the default settings (see Fig. 5a), three engineers appear in the result who also held lectureships at TU Dresden and TH Dresden. After a series of parameter changes (reducing the weight for lectureships and assistances, increasing the weight for subjects, and choosing *professor* (Prof.) as mandatory position), two other engineers are listed as having a higher subjects similarity (see Fig. 5b).

C. Comparative Analysis of Subjects

In order to contrast different sets of subjects dependent on certain biographical criteria, we adapted TagPies [14] for the Prosopographic Database of Engineers to support comparative analyses. We offer different major categories to choose as the basis for comparison: subjects, time ranges, universities, university types and memberships. Once the user has selected different features for the chosen category, the subjects that are associated with the corresponding engineers having these features are grouped and form the slices of the TagPie. For example, when universities are the major category, and the three *universities* TH Braunschweig, TH Aachen and TH Dresden are selected, all subjects taught at these universities can be compared.

Comparing time ranges: Figure 6 compares the subjects taught in the time ranges 1926-1950 and 1951-1975. Subjects only taught between 1926-1950 are colored orange, subjects only taught between 1951-1975 are colored green, and subjects are colored black if they were taught in both time ranges. So, a change of the use of technical terms can be examined. For example, the subjects *Flugmotoren* (aircraft engines) and *Fahrzeugmotoren* (craft engines) thematized the construction of engines dependent on the vehicle type between 1926 and 1950. Later, those subjects were replaced by the subjects called *Verbrennungsmotoren* (internal combustion engine) and *Dieselmotoren* (diesel engine) focusing on engine types.

Comparing co-occurring subjects: Initial research questions focused on analyzing the comparative geospatial-temporal developments of engineering branches *Werkstoffe* (materials), *Konstruktion* (construction) and *Fertigung* (manufacturing). Figure 7 illustrates the co-occurring subjects of engineers who taught the eponymous subjects. Although only subjects (not branches) are chosen as main categories, nearly disjoint subject fields are received as most of the subject terms are only presented in the one branch and only a few centrally placed tags are colored black, thus, co-occur with multiple branches. This visualization was used as an entry point for constructing engineering branches.

D. Composing Engineering Branches

Analyzing and comparing the geospatial-temporal development of different engineering branches is with the above mentioned visualizations only rudimentarily doable as neither assignments of subjects to branches nor assignments of branches to engineers were given. To do so, we developed an interactive tag cloud interface that enables the interactive

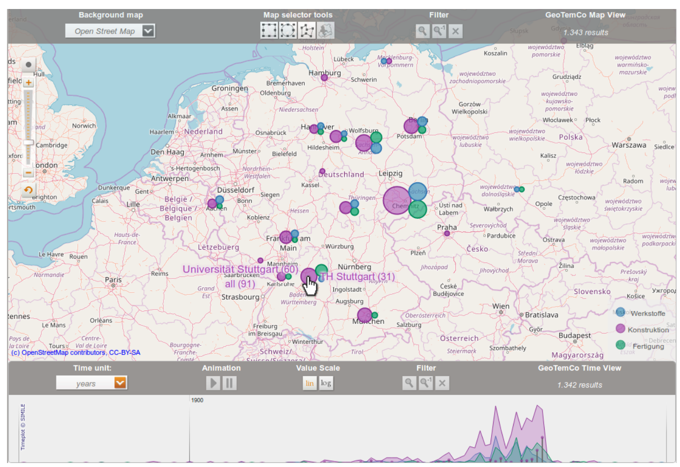
Fig. 6: Comparing subjects taught in two time ranges

Fig. 7: Comparing co-occurring subjects

composition of branches. Once the high-level branches that are likewise listed as subjects are selected, the tag cloud gives an overview on (1) the frequencies of subjects, and (2) co-occurring subjects (other subjects that an engineer taught who also taught a higher-level branch) on mouseover. Via mouse click, subjects can be assigned to one or multiple branches, thus, branches can be iteratively composed. With the branches at hand, they can be compared in a geospatial-temporal context using GeoTemCo.

(a) *Wärmelehre* (thermodynamics) only co-occurs with subjects already assigned to *Konstruktion*.

(b) *Schweißtechnik* (welding engineering) co-occurs with subjects related to all engineering branches.



(c) Geospatial-temporal analysis of branch developments.

Fig. 8: Composing the engineering branches *Werkstoffe*, *Fertigung* and *Konstruktion*

Comparing three engineering branches: Figure 8 shows the tag cloud environment when composing the engineering branches *Werkstoffe* (materials), *Fertigung* (manufacturing) and *Konstruktion* (construction). When a subject is selected, co-occurring subjects are highlighted (bold font and underlined). For example, when selecting the subject *Wärmelehre* (thermodynamics), a number of subjects already assigned to the construction branch stick out (see Fig. 8a). Thus, we also assign thermodynamics to construction. When selecting *Schweißtechnik* (welding engineering), subjects related to all engineering branches are highlighted 8b. Depending on the research question, the subject might be added to all or none of the branches in such a case. Once the three branches are composed, their geospatial-temporal development can be comparatively analyzed. Due to the high number of assignments to the construction branch, in all regions, construction is the most prominent branch. While construction subjects became prominent in West Germany in the late 1960s (e.g., the Stuttgart region as shown in Fig. 8c), construction subjects were prominent earlier in East Germany, where manufacturing subjects were more frequently taught in the late 1960s.

V. Discussion

The most important issue to be solved in the project was mapping the initial research questions of the historians to the given database. Although we were able to deliver visual interfaces capable of investigating those questions, it is important to note that in the process of collecting data—what has been done manually—an appropriate data model should be constructed in order to avoid mismatches between database and research interest. When visualization scholars were involved in this project, the data acquisition was already finished, and it was not possible to annotate the necessary biographical information.

Defining appropriate rules to extract subjects, universities and datings of an engineer's tenures was an iterative process that gradually reduced the number of false positive subject terms. As sometimes, in the process of writing down information on employments of engineers when building the database, the recurring pattern was mistakenly broken by the historian, a few false positives were still required to be manually removed.

Composing the engineering branches with our tool needs to be done carefully. It turned out that, in the first place, only unambiguous subjects should be assigned to branches that should grow evenly. Focusing only one branch may end up in over- and under-representations.

Finally, it remains to be said that, as in many other interdisciplinary digital humanities projects [5], [13], [21], the visualizations do not serve to deliver concrete answers to the posed research questions. The purpose is rather to generate new perspectives on a known dataset, for the first time in the form of interactive visualizations, capable of triggering new hypotheses on the observed topic.

VI. Conclusion

We presented a series of visual interfaces designed in collaboration with historians for the purpose of interactively exploring and analyzing the Prosopographic Database of German Engineers 1825–1970. The initial research questions could not be solved straightforwardly as the necessary information was not structurally accessible. Using a rule-based named entity recognition method, we could assign subjects, universities and datings of the corresponding tenures to engineers. This enabled visual analyses of the database and the profiling of engineers with similar characteristics. A further tool enabled the composition of branches based on subjects in order to support investigating the initial research questions concerning the comparative analysis of the geospatial-temporal developments of different engineering branches.

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